AUTOMATIC VISUAL INSPECTION SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

Notice: More than one reissue application has been filed for the reissue of U.S. Pat. No. 5,774,572. The reissue applications are application numbers: Appl. No. 09/607,318, filed Jun. 30, 2000 (the present parent reissue application), and Appl. No. 10/151,248, filed May 21,2002 (a continuation reissue application of the present parent reissue application), all of which are reissues of U.S. Pat. No. 5,774,572.

This application is a continuation of application Ser. No. 07/961,070, filed Oct. 14, 1992, now abandoned, which is a continuation of application Ser. No. 07/804,511, filed Dec. 10, 1991, now abandoned; which is a continuation of application Ser. No. 06/684,583, filed Dec. 20, 1984, now abandoned.

TECHNICAL FIELD OF THE INVENTION

This invention relates to automatic visual inspection systems, more particularly to systems for inspecting printed circuit boards, hybrid boards, and integrated circuits.

BACKGROUND OF THE INVENTION

In its simplest form, a printed circuit board or panel comprises a non-conductive substrate on one or both surfaces of which are deposited conductive tracks or lines in a pattern dictated by the design of the electronic equipment supported by the board. More complex boards are constructed by laminating a number of single panels into a composite or multi-layered board; and the use of the latter has increased dramatically in recent years in an effort to conserve space and weight.

As component size has shrunk, component density on boards has increased with the result that line size and spacing have decreased over the years. Because of the "fine geometry" of modern boards, variations in line width and spacing have become more critical to proper operation of the boards. That is to say, minor variations in line thickness or spacing have a much greater chance to adversely affect performance of the printed circuit board. As a consequence, visual inspection, the conventional approach to quality control, has employed visual aids, such as magnifiers or microscopes, to detect defects in a board during its manufacture. Such defects would include line width and spacing, pad position relative to hole location, etc. Unfortunately, visual inspection is a time consuming, tedious task that causes operator fatigue and consequential reduction in consistancy and reliability of inspection, as well as throughput.

Because multi-layered boards cannot be tested electrically before lamination, visual inspection of the component panels of a multi-layered board before lamination is critical. A flaw in a single layer of an assembled board can result in scrapping of the entire board, or involve costly, and time consuming rework. Thus, as board complexity and component density and production requirements have increased, automation of manufacturing processes has been undertaken. However, a larger and larger fraction of the of producing boards lies in the inspection of the boards during various stages of manufacture.

Automatic visual inspection techniques have been developed in response to industry needs to more quickly, accurately and consistently inspect the printed circuit boards. Conventional systems include an electro-optical sub-system that intensely illuminates a board being inspected along a narrow strip perpendicular to the linear displacement of the board through the system, and a solid state camera that converts the brightness of each elemental area of the illuminated strip, termed a pixel, to a number representative of such brightness; and the number is stored in a digital memory. Scanning of the entire board is achieved by moving the board relative to the camera. The result is a grey scale image of the board, or part of the board stored in memory. A relatively small number in a cell of the memory represents a relatively dark region of the object (i.e., the substrate), and a relatively large number represents a brighter portion of the object, (i.e., a conductive line).

The contents of the memory are processed for the purpose of determining the location of transitions between bright and dark regions of the object. Such transitions represent the edges of lines and the processing of the data in the digital memory is carried out so as to produce what is termed a binary bit map of the object which is a map of the printed circuit board in terms of ZERO's and ONE's, where the ONE's trace the lines on the printed circuit board, and the ZERO's represent the substrate. Line width and spacing between lines can then be carried out by analyzing the binary map.

The time required to scan a given board, given a camera with a predetermined data processing rate, typically 10–15 MHz, will depend on the resolution desired. For example, a typical camera with an array of 2048 photodiodes imaging a board is capable of scanning a one inch swath of the board in each pass if a resolution of ½ mil is required. At 0.5 mil resolution, a swath one inch wide and 24 inches long is composed of 96 million pixels. Assuming camera speed of 10 MHz, about 10 seconds would be required for completing one pass during which data from one swath would be acquired. If the board were 18 inches wide, then at least 18 passes would be required to complete the scan of the board. More than 18 passes is required, however, to complete a scan of the board because an overlap of the passes is required to insure adequately covering the "seams" between adjacent passes. Combined with overhead time required, e.g., the time required to reposition the camera from swath to swath, data acquisition time becomes unacceptably large under the conditions outlined above.

The basic problems with any automatic visual inspection system can be summarized in terms of speed of data acquisition, amount of light to illuminate the board, and the depth of field of the optical system. Concomitant with increased requirements for reducing pixel size (i.e., increasing resolution) is an increase in the amount of light data acquisition. Physical constraints limit the amount of light that can be concentrated on the printed circuit boards so that decreasing the pixel size to increase resolution and detect variations in line width or spacing of "fine geometry" boards, actually slows the rate of data acquisition. Finally, decreasing pixel size, as resolution is increased, is accompanied by a reduction in the depth of field which adversely affects the accuracy of the acquired data from board to board.

It is therefore an object of the present invention to provide a new and improved automatic visual inspection system which is capable of acquiring data faster than conventional automatic visual inspection systems, and/or reducing the amount of illumination required for the board, and increasing the depth of field.

BRIEF DESCRIPTION OF INVENTION

According to the present invention, a binary map of an object having edges is produced by first producing a digital